

A preliminary checklist of the freshwater snails of Sabah (Malaysian Borneo) deposited in the BORNEENSIS collection, Universiti Malaysia Sabah

Ting Hui Ng^{1,2}, Jasrul Dulipat³, Junn Kitt Foon³,
Manuel Lopes-Lima⁴, Alexandra Zieritz⁵, Thor-Seng Liew³

1 Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, Singapore 117543, Republic of Singapore **2** Department of Biology, Faculty of Science, Chulalongkorn University, Phayathai Road, Pathumwan District, Bangkok 10330, Thailand **3** Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88450 Kota Kinabalu, Sabah, Malaysia **4** CIBIO/InBIO - Research Center in Biodiversity and Genetic Resources, Universidade do Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485-661 Vairão, Portugal **5** School of Environmental and Geographical Sciences, University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Malaysia

Corresponding author: Thor-Seng Liew (thorsengliew@gmail.com)

Academic editor: F. Köhler | Received 6 March 2017 | Accepted 25 April 2017 | Published 15 May 2017

<http://zoobank.org/EACC134E-B3FD-4545-B5DC-DD79E81EE9BD>

Citation: Ng TH, Dulipat J, Foon JK, Lopes-Lima M, Zieritz A, Liew T-S (2017) A preliminary checklist of the freshwater snails of Sabah (Malaysian Borneo) deposited in the BORNEENSIS collection, Universiti Malaysia Sabah. ZooKeys 673: 105–123. <https://doi.org/10.3897/zookeys.673.12544>

Abstract

Sabah, a Malaysian state at the north-eastern tip of Borneo, is situated in one of the Earth's biodiversity hotspots yet its freshwater gastropod diversity remains poorly known. An annotated checklist of the freshwater gastropods is presented, based on specimens deposited in the BORNEENSIS collection of the Institute for Tropical Biology and Conservation at Universiti Malaysia Sabah, Malaysia. A KMZ file is also provided, which acts as a repository of digital images and complete collection data of all examined material, so that it can be shared and adapted to facilitate future research.

Keywords

Diversity, Kalimantan, Mollusca, non-marine gastropods, North Borneo, Sarawak

Introduction

Mollusca is the second most diverse animal phylum after Arthropoda, and nearly 4000 species of gastropods have been described from freshwater habitats alone (Strong et al. 2008). Freshwater gastropods achieve the highest diversity and endemism in tropical South-east Asia which includes the ancient lakes of Sulawesi (Indonesia) and Inle (Myanmar), as well as large river systems like the Mekong river basin (Strong et al. 2008). However, the total number of known species might represent only half of the species diversity, and many species remain to be discovered and described (Lydeard et al. 2004). In addition, although the IUCN conservation status has been assessed for only approximately 10% of these known species, freshwater gastropods account for 20% of recorded mollusc extinctions (Lydeard et al. 2004, Strong et al. 2008).

Although the number of extinct molluscs recorded in Asia is far less than other regions (Régnier et al. 2009), it may not reflect the reality that Asian malacofauna face a vast variety of threats (Köhler et al. 2012). Rather, this paradox is more likely due to the expertise and knowledge of freshwater gastropod being biased towards other regions (Bouchet 1997, Cuttelod et al. 2011, Johnson et al. 2013). Despite the high diversity of freshwater molluscs in South-east Asia, research involving freshwater snails has been mainly concentrated on the field of medical malacology, with most of the focus being on the zoonotic parasites hosted by these snails (e.g., Lim et al. 1976, TROPMED Medical Group 1986). As a result, little else is known about the molluscan hosts themselves. Seminal work done by van Benthem Jutting (e.g., 1956, 1959) and Brandt (1974) provided the most comprehensive insights into the diversity and distribution of freshwater molluscs in Indonesia, parts of Peninsular Malaysia, and Thailand. Decades later little progress has been made to update the information, where large knowledge gaps remain in the biodiversity, ecology and physiology of South-east Asian freshwater molluscs (Köhler et al. 2012).

Borneo, the third largest island in the world, is regarded as one of the Earth's biodiversity hotspots because of its high species richness and endemism and its highly threatened habitats (Myers et al. 2000). The overall diversity of freshwater gastropods in Borneo, however, remains poorly known compared to the rest of South-east Asia. Previous faunistic studies recorded not more than 30 freshwater gastropod species from Borneo (Issel 1874, Bock 1881, Aldrich 1889, von Martens and Thiele 1908, Solem 1964, Hill et al. 1997, Köhler and Glaubrecht 2002, Shabdin 2010, Ng et al. 2015a). In contrast, more than 300 freshwater gastropod species have been recorded in Indochina (Thailand, Myanmar, Laos, Cambodia) (Brandt 1974, Köhler et al. 2012) and from areas much smaller than Borneo. For example, in Java, more than 60 species are known (Marwoto et al. 2011) and in Singapore, around 20 species have been recorded (Clements et al. 2006, Tan et al. 2012, Ng et al. 2014, 2015b, 2016a, 2016b, 2016c).

In Borneo and particularly in the northern Malaysian state of Sabah (Figure 1), a complete species list that is based on primary data (i.e., based on accessible museum collections) does not exist. Previous studies of selected freshwater snails that focused



All the specimens were catalogued using the *BORNEENSIS* Mollusca Collection in-house database, under the prefix of BOR/MOL #### to serve as stable specimen identifiers for future interrogation (e.g. Page 2016). In addition to the species list and representative images for each species, we also created a KMZ file as a repository of digital images and complete collection data of all the examined materials. All the specimen data are published under Creative Common license CC BY 4.0 so that it can be shared and adapted to facilitate future research (Meier and Dikow 2004, Miller et al. 2015). As the collection is based on a small number of surveys, this checklist is not a

complete checklist for Sabah freshwater gastropods but it serves as a starting point to explore the diversity and taxonomy of freshwater gastropods not only in Sabah, but also for the rest of Borneo.

Materials and methods

The freshwater gastropods deposited in the *BORNEENSIS* collection, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Malaysia (BOR/MOL), presently consists of 49 dry collection lots and 76 wet collection lots. A total of 849 specimens (between 1 and 59 specimens per lot) were examined. Approximately half of the collection lots were collected in 2016 by J. Dulipat, A. Zieritz, M. Lopes-Lima and T.S. Liew, whereas the rest were collected between 1997 and 2014. Most of the collections were made on the west coast of Sabah (Figure 1). The majority of the specimens were collected opportunistically and picked by hand and it is likely that smaller species were missed.

Identification was done to species level based on the shell morphology by referring to H. Adams (1874), A. Adams (1885), Smith (1894, 1895), von Martens and Thiele (1908), van Benthem Jutting (1956), Brandt (1974), and Tan et al. (2012). Synonymy follows Brandt (1974), Köhler and Glaubrecht (2001), Glaubrecht et al. (2009), Cowie (2015), and Eichhorst (2016). Distribution of each species in the checklist was summarised from the collection information, some of which contain words in the Malay language – *pulau*: island, *gua*: cave, *sungai*: river. The exact GPS coordinates for each collection lot was specified. If no exact GPS coordinates were available for a collection lot, approximate GPS coordinates were determined based on available locality information. Representative specimens of each of the collection lots were photograph using a single-lens reflex camera. Lastly, a KMZ file was created which consists of a main KML file and a supporting folder with all the photographs taken from each collection lot.

Results and discussion

In total, 18 species were identified, from 14 genera and nine families of freshwater gastropods, including four non-native species. Their details are provided in the checklist below. The number of species recorded in this list is similar to that of Singapore (20 species), which has a much smaller landmass compared to Sabah (Clements et al. 2008, Ng et al. 2014, 2015, 2016b, 2016c). As such, it is clear that this list represents only a small fraction of the total freshwater gastropod diversity in Sabah which, together with bivalves, have been estimated to be 100 species (Solem 1964). Nevertheless, this checklist presents complete specimen information (Suppl. materials 1 and 2) for nearly two-thirds of previously known taxa in Borneo (Issel 1874, von Martens and Thiele 1908, Solem 1964, Hill et al. 1997, Shabdin 2010, Ng et al. 2015a).

Systematics

Family AMPULLARIIDAE Gray

Genus *Pila* Röding, 1798

Pila ampullacea (Linnaeus, 1758)

Figure 2A

Synonyms. *Helix ampullacea* Linnaeus, 1758; *Ampullaria sumatrensis* Philippi, 1851; *Ampullaria magnifica* Philippi, 1852; *Ampullaria turbinis* Lea, 1856; *Ampullaria ampullacea* var. *javensis* Nevill, 1885; *Ampullaria turbinis* var. *subglobosa* Nevill, 1885; *Ampullaria turbinis* var. *subampullacea* Nevill, 1885; *Ampullaria dalyi* Blanford, 1903; *Pachylabra turbinis* race *lacustris* Annandale, 1920.

Material examined. BOR/MOL3378, BOR/MOL3773, BOR/MOL3775, BOR/MOL8671, BOR/MOL8673, BOR/MOL8675, BOR/MOL8708.

Distribution and habitat. Labuan, along the north-west coast of Sabah from Kota Belud, Kota Kinabalu, Penampang, to Papar, and in the interior town of Nabawan. Habitats include freshwater and mangrove swamps, ponds, and rivers.

Remarks. This species was purchased on two separate occasions (BOR/MOL3773, BOR/MOL8708), ten years apart, from the same native market in Penampang.

Pila scutata (Mousson, 1848)

Figure 2B

Synonyms. *Ampullaria conica* W. Wood, 1828; *Ampullaria orientalis* Philippi, 1849; *Ampullaria borneensis* Philippi, 1852; *Ampullaria lubrica* Reeve, 1856; *Ampullaria vitata* Reeve, 1856; *Ampullaria complicata* Reeve, 1856; *Ampullaria stoliczkana* Nevill, 1877; *Ampullaria wellesleyensis* de Morgan, 1885; *Pachylabra javanica* var. *fruhstorferi* Kobelt, 1912; *Pachylabra* (*lubrica* var.?) *quadrasi* Kobelt, 1912.

Material examined. BOR/MOL1758.

Distribution and habitat. The single specimen was collected from a limestone hill in the Lower Kinabatangan valley.

Remarks. The species has previously been recorded from Tuaran and appeared to have been eaten by local communities (Lim et al. 1976).

Genus *Pomacea* Perry, 1810

Pomacea sp.

Figure 2C

Material examined. BOR/MOL537, BOR/MOL1759, BOR/MOL8672, BOR/MOL8711.

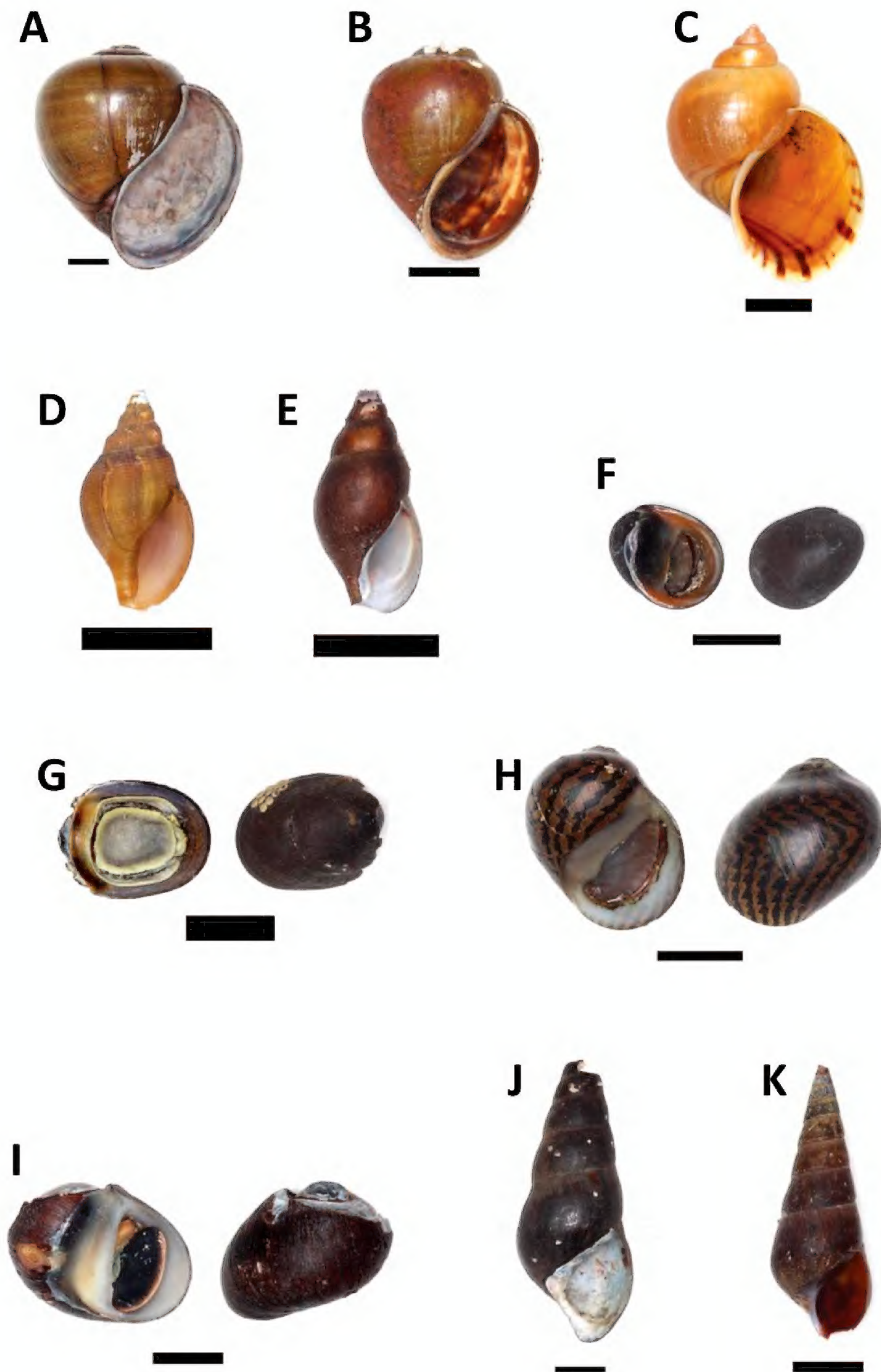


Figure 2. **A–C** Family Ampullariidae. **A** *Pila ampullacea* (Linnaeus, 1758) – BOR/MOL 8673 **B** *Pila scutata* (Mousson, 1848) – BOR/MOL 1758. **C** *Pomacea* sp. – BOR/MOL 1759 **D–E** Family Nassariidae **D** *Clea bangueyensis* EA Smith, 1895 – BOR/MOL 3397 **E** *Clea* sp. – BOR/MOL 8304 **F–I** Family Neritidae **F** *Neritina pulligera* (Linnaeus, 1767) – BOR/MOL 6705 **G** *Septaria porcellana* (Linnaeus, 1858) – BOR/MOL 8292 **H** *Vittina coromandeliana* (Sowerby, 1836) – BOR/MOL 8303. **I** *Vittina variegata* (Lesson, 1831) – BOR/MOL 6723 **J–K** Family Pachychilidae: *Sulcospira pageli* (Thiele, 1908) **J** BOR/MOL 1753 **K** BOR/MOL 3394. Scale bars 10 mm.

Distribution and habitat. Along the north-western coast from Kota Marudu to Kota Kinabalu and Tenom, and in the interior at Keningau. Habitats include freshwater swamps, rivers, and drains.

Remarks. Ampullariids of the genus *Pomacea* originate from South America and are globally-invasive, causing widespread damage to paddy fields in South-east Asia (Joshi and Sebastian 2006). The harm brought about by *Pomacea* prompted various studies to control their spread, including in Sabah (Teo 2001, 2003, 2004). *Pomacea canaliculata* was first recorded from the state in 1992 (Yahaya et al. 2006), and has previously been found in paddy fields in Tuaran, Tambunan and Keningau (Teo 2004). Another species, the morphologically similar *Pomacea maculata*, has been widely introduced to South-east Asia (Hayes et al. 2008, 2012) and may also be established in Sabah. However, fresh materials were unavailable to confirm the identity of *Pomacea* from Sabah using molecular methods, which are the best for distinguishing between the species (Matsukura et al. 2013).

Family NASSARIIDAE Iredale

Genus *Clea* H Adams & A Adams, 1855

Clea bangueyensis EA Smith, 1895

Figure 2D

Material examined. BOR/MOL552, BOR/MOL553, BOR/MOL554, BOR/MOL1762, BOR/MOL3105, BOR/MOL3385, BOR/MOL3396, BOR/MOL3397, BOR/MOL3595, BOR/MOL6719, BOR/MOL8676.

Distribution and habitat. From northern to eastern Sabah: Kinabalu Park, Danum Valley, Tabin Wildlife Reserve, Kunak, and Tawau, and in the interior in Nabawan and Keningau. Collected from rivers and streams, some in the vicinity of limestone hills.

Remarks. This species was first described from Pulau Banggi, off the north-east coast of Sabah.

Clea sp.

Figure 2E

Material examined. BOR/MOL8293, BOR/MOL8304, BOR/MOL8312, BOR/MOL8700.

Distribution and habitat. Found from two localities close to Kota Kinabalu, rivers on the offshore island of Pulau Gaya, and Kiansom forest, approximately 20km from the city.

Remarks. This species lacks the spiral striae of *Clea bangueyensis* and lacks the transverse striae of *Clea nigricans* A Adams, 1885, which was described from the neighbouring state of Sarawak (Adams 1885).

Family NERITIDAE Rafinesque**Genus *Neritina* Lamarck, 1816*****Neritina pulligera* (Linnaeus, 1767)**

Figure 2F

Synonyms. *Neritina rubella* Müller, 1774; *Neritina oculus* Röding, 1798; *Nerita rossmassleriana* Récluz, 1846; *Neritina larga* Hombron & Jacquinot, 1848; *Neritina brandti* Philippi, 1849; *Neritina pulligera subcanalis* Mousson, 1865; *Neritina subcanalis* Mousson, 1870; *Neritina sulcata* Tennison-Woods, 1878; *Neritina sumatrana* Dautzenberg, 1899.

Material examined. BOR/MOL6705, BOR/MOL6713, BOR/MOL7929, BOR/MOL8294, BOR/MOL8298, BOR/MOL8301, BOR/MOL8308, BOR/MOL8311.

Distribution and habitat. Labuan. The south-east in Tawau, and the north-west on Pulau Gaya and from Kota Kinabalu.

Remarks. This species is generally found in clear, coastal freshwater streams and rivers from Okinawa, and south through South-east Asia and Australasia (van Benthem Jutting 1956, Brandt 1974, Eichhorst 2016).

Genus *Septaria* Ferrusac, 1807***Septaria porcellana* (Linnaeus, 1858)**

Figure 2G

Synonyms. *Navicella aponogetonis* Vahl, 1795; *Sandalium pictum* Schumacher, 1817; *Navicella suborbicularis* Sowerby, 1825; *Navicella depressa* Lesson, 1831; *Navicella zebra* Lesson, 1931; *Navicella gaimardi* Récluz, 1841; *Navicella quoyi* Récluz, 1841; *Navicella affinis* Mousson, 1865; *Navicella fissa* Mousson, 1869; *Navicella haustum* Reeve, 1856; *Navicella orbicularis* Reeve, 1856; *Navicella squamata* Dohrn, 1858; *Navicella pulcherrima* Tapparone-Canefri, 1883.

Material examined. BOR/MOL8292, BOR/MOL8302, BOR/MOL8307.

Distribution and habitat. All lots were collected from rivers of Pulau Gaya, off the coast of Kota Kinabalu.

Remarks. This species is widespread in coastal freshwater streams, rivers and lakes from Sri Lanka to Australasia (van Benthem Jutting 1956, Eichhorst 2016).

Genus *Vittina* HB Baker, 1924***Vittina coromandeliana* (Sowerby, 1836)**

Figure 2H

Synonyms. *Nertina cochinsinae* Récluz, 1850; *Nerita ramosa* Meuschen, 1787; *Neritina paralella* Röding, 1798; *Neritina lugubris* Lamarck, 1822; *Neritina coromandeliana* Sowerby,

1836; *Neritina triangularis* Mörch, 1852; *Neritina pulcherrima* Mousson, 1857; *Neritina interstitialis* von Martens, 1877; *Neritina hieroglyphica* Wattlebled, 1886.

Material examined. BOR/MOL8303.

Distribution and habitat. Single lot collected from Kuari River on Pulau Gaya.

Remarks. This species can be found in brackish estuarine areas (streams and mangrove swamps) from Japan through South-east Asia to Australasia, and India (Brandt 1974, Eichhorst 2016).

Vittina variegata (Lesson, 1831)

Figure 2I

Synonyms. *Neritina pulchra* Sowerby, 1836; *Neritina cuvieriana* Récluz, 1841; *Neritina turrita* Schmeltz, 1866; *Neritina granulosa* Schmeltz, 1869; *Nertina zelandicus* Mousson, 1869; *Neritella granulum* Schmeltz, 1974.

Material examined. BOR/MOL6723.

Distribution and habitat. Single lot collected from a river on Pulau Bohey Dulang, off the eastern town of Semporna.

Remarks. This species can be found in coastal freshwater bodies in South-east Asia and Australasia, and the Pacific islands (van Benthem Jutting 1956, Brandt 1974, Eichhorst 2016).

Family PACHYCHILIDAE P Fischer & Crosse

Genus *Sulcospira* Troschel, 1858

Sulcospira pageli (Thiele, 1908)

Figure 2J,K

Synonym. *Melania schmidtii* Martens, 1908.

Material examined. BOR/MOL542, BOR/MOL543, BOR/MOL544, BOR/MOL547, BOR/MOL548, BOR/MOL550, BOR/MOL1752, BOR/MOL1753, BOR/MOL3100, BOR/MOL3394, BOR/MOL3450, BOR/MOL3457, BOR/MOL3761, BOR/MOL3825, BOR/MOL5947, BOR/MOL5950, BOR/MOL6707, BOR/MOL6709, BOR/MOL6711, BOR/MOL6715, BOR/MOL6717, BOR/MOL6718, BOR/MOL6722, BOR/MOL8693, BOR/MOL8694, BOR/MOL8695, BOR/MOL8696, BOR/MOL8697, BOR/MOL8698, BOR/MOL8701.

Distribution and habitat. West from Kota Marudu to Kota Kinabalu, in the interior in Tenom and Keningau, and eastern Sabah in Beluran, Kinabatangan, Lahad Datu, Kunak, Tawau. Found in forest streams and in the vicinity of limestone caves, rivers, and in streams along paddy fields.

Remarks. This species has previously been synonymised with *Sulcospira schmidtii* (Martens, 1908), which was also originally described from Borneo (Köhler and Glaubrecht 2001). Shells appear to be highly plastic, with material examined having shells

with rounded or pointed basal lips, with or without raised ribs, and with or without spiral striae at the bottom of final body whorl. Other species of *Sulcospira* have previously been described from Borneo (see e.g., Köhler and Glaubrecht 2001, 2002, Köhler and Dames 2009), but pending further analysis and availability of fresh material for molecular sequencing, we tentatively consider all material conspecific.

Family VIVIPARIDAE Gray

Genus *Sinotaia* Haas, 1839

Sinotaia guangdungensis (Kobelt, 1906)

Figure 3A

Material examined. BOR/MOL8674, BOR/MOL8709.

Distribution and habitat. Collected from a paddy field stream in Kota Marudu, and from a pond in Nabawan.

Remarks. *Sinotaia guangdungensis* is native to Southern China and has to date, been introduced to Peninsular Malaysia, Singapore, and Australia (Ng et al. 2014). This is a first record for Sabah.

Family PALUDOMIDAE Stoliczka

Genus *Paludomus* Swainson, 1840

Paludomus everetti EA Smith, 1894

Figure 3B

Material examined. BOR/MOL545, BOR/MOL1226, BOR/MOL1227, BOR/MOL1754, BOR/MOL1755, BOR/MOL1756, BOR/MOL3127, BOR/MOL3398, BOR/MOL3596, BOR/MOL5853, BOR/MOL5870.

Distribution and habitat. Eastern Sabah in Kunak, Danum Valley, Tawau, and Kinabatangan. Found in forest streams and in the vicinity of limestone caves.

Remarks. Originally described from Batang Lupar in neighbouring Sarawak, and Gua Gomantong in the Kinabatangan area. The material in *BORNEENSIS* include shells collected from the vicinity of Gua Gomantong.

Paludomus luteus Adams, 1874

Figure 3C

Material examined. BOR/MOL1225.

Distribution and habitat. Single lot found in the vicinity of Gua Gomantong in the Kinabatangan area.

Remarks. Distinguished from *Paludomus everetti* by the lack of spiral striae at the suture.

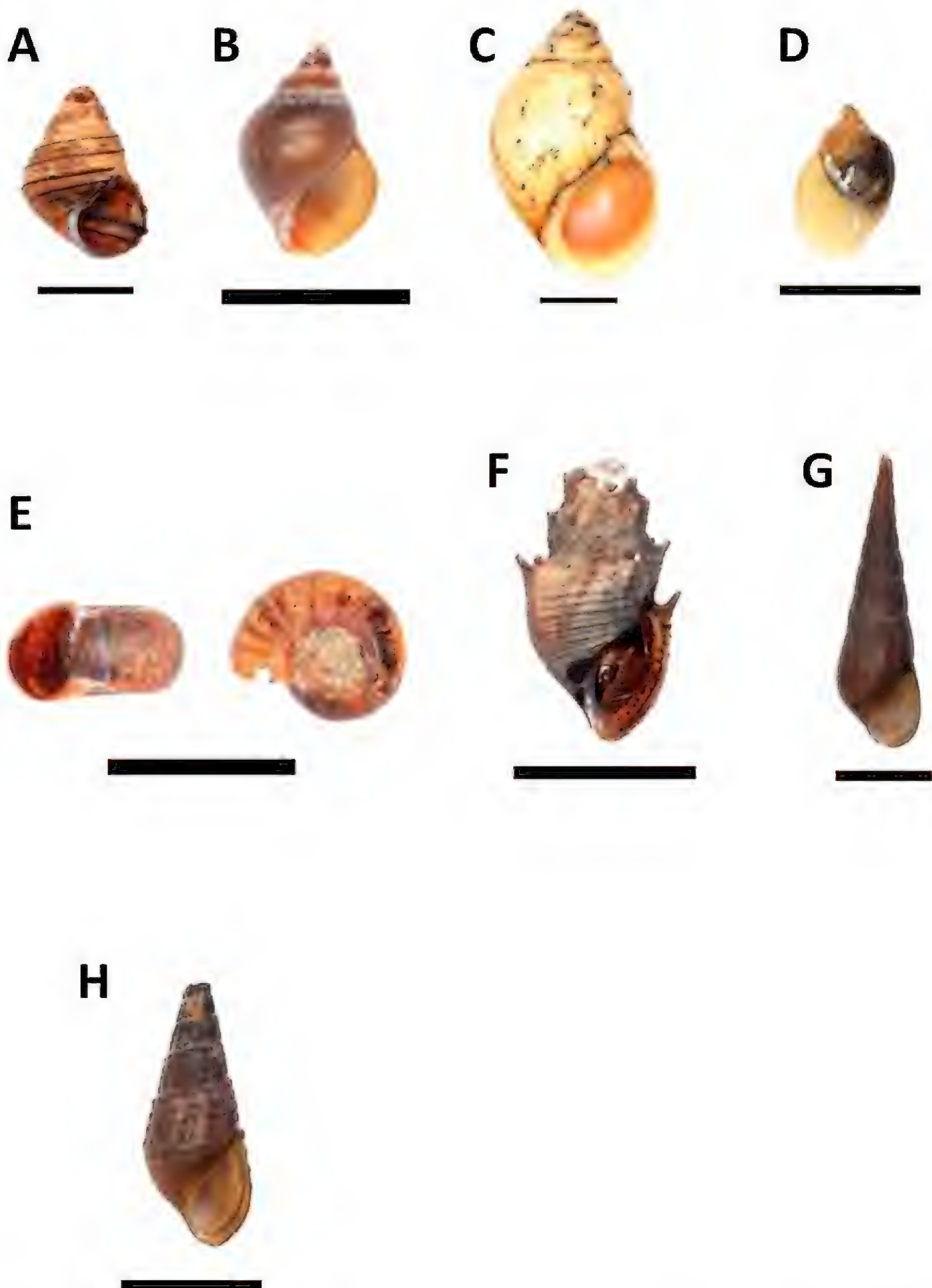


Figure 3. **A** Family Viviparidae: *Sinotaia guangdungensis* (Kobelt, 1906) – BOR/MOL 8709 **B–C** Family Paludomidae. **B** *Paludomus everetti* EA Smith, 1894 – BOR/MOL 3398 **C** *Paludomus luteus* Adams, 1874 – BOR/MOL 1225 **D** Family Physidae: *Physa acuta* Draparnaud, 1805 – BOR/MOL 3451 **E** Planorbidae *Indoplanorbis exustus* (Deshayes, 1834) – BOR/MOL 8681 **F–H** Family Thiaridae **F** *Mieniplotia scabra* (OF Müller, 1774) – BOR/MOL 8310 **G** *Melanoides tuberculata* (OF Müller, 1774) – BOR/MOL 6799 **H** *Tarebia granifera* (Lamarck, 1822) – BOR/MOL 8688. Scale bars 10 mm.

Family PHYSIDAE Fitzinger**Genus *Physa* Draparnaud, 1801*****Physella acuta* (Draparnaud, 1805)**

Figure 3D

Material examined. BOR/MOL3451.**Distribution and habitat.** Single lot collected from Kiansom forest, 20km inland from Kota Kinabalu.**Remarks.** This species is native to North America and has been widely introduced to neighbouring Sarawak and Brunei, on Borneo (Ali 1993, Ng et al. 2015b). This appears to be the first record of the species in Sabah.**Family PLANORBIDAE Rafinesque****Genus *Indoplanorbis* Anandale & Prashad, 1920*****Indoplanorbis exustus* (Deshayes, 1834)**

Figure 3E

Material examined. BOR/MOL6716, BOR/MOL8681.**Distribution and habitat.** Collected from rivers in Tawau and Tuaran.**Remarks.** *Indoplanorbis exustus* has a wide distribution across Asia and is an intermediate host of zoonotic parasites (Liu et al., 2010). In Peninsular Malaysia, the species has been shown to host *Schistosoma spindale*, that causes cercarial dermatitis in infected humans (Chiew et al. 2009). The snail was not recorded from Tuaran in the 1970's (Lim et al. 1976), and both lots in BORNEENSIS were only collected in 2016.**Family THIARIDAE Gill****Genus *Mieniplotia* Low & Tan, 2014*****Mieniplotia scabra* (OF Müller, 1774)**

Figure 3F

Synonyms. *Helix aspera* Gmelin, 1791; *Melania spinulosa* Lamarck, 1822; *Melania doreyana* Lesson, 1831; *Melania spinescens* Lesson, 1831; *Melanium granum* von dem Busch, 1842; *Melania scabrella* Mousson, 1848; *Melania acanthica* Lea, 1850; *Melania denticulata* Lea, 1850; *Melania pagoda* Lea, 1850; *Melania datura* Dohrn, 1858; *Melania elegans* Reeve, 1859; *Melania pugilis* Reeve, 1859; *Melania rugosa* Brot, 1860; *Melania snellemanni* Schepman, 1880; *Melania bockii* Brot, 1881; *Melania savinieri* Morlet, 1884; *Melania subcancellata* Boettger, 1890; *Melania pinguicola* Martens in Weber, 1897; *Melania varia* Bullen, 1904; *Melania intrepida* Fulton, 1914; *Melania sykesi* Degner, 1928.

Material examined. BOR/MOL8300, BOR/MOL8306, BOR/MOL8310, BOR/MOL8690.

Distribution and habitat. Off Kota Kinabalu on Pulau Gaya, and northern Sabah in Pitas. Collected from rivers.

Remarks. This cryptogenic species is widespread across tropical Asia and is invasive around the world (Cianfanelli et al. 2016).

Genus *Melanoides* Olivier, 1804

Melanoides tuberculata (OF Müller, 1774)

Figure 3G

Synonym. *Melanoides fasciolata* Olivier, 1804.

Material examined. BOR/MOL551, BOR/MOL1760, BOR/MOL1761, BOR/MOL6708, BOR/MOL6720, BOR/MOL6724, BOR/MOL6725, BOR/MOL6799, BOR/MOL7930, BOR/MOL7931, BOR/MOL8295, BOR/MOL8296, BOR/MOL8297, BOR/MOL8299, BOR/MOL8305, BOR/MOL8309, BOR/MOL8427, BOR/MOL8444, BOR/MOL8682, BOR/MOL8692, BOR/MOL8699.

Distribution and habitat. Labuan. Widely-distributed throughout the state and on offshore islands, including Tenom, Kota Kinabalu, Pulau Gaya, Pulau Tiga, Tuaran, Kota Belud, Tawau, and Pulau Bohey Dulang and Pulau Bodgaya, off Semporna. Recorded from rivers, paddy fields, and concrete drains.

Remarks. This species originates from West Asia and East Africa but has become widespread and invasive across the world (Pointier 1999).

Genus *Tarebia* H Ada & A Adams, 1884

Tarebia granifera (Lamarck, 1822)

Figure 3H

Synonyms. *Helix lineata* Gray in Wood, 1828; *Melania celebensis* Quoy & Gaimard, 1834; *Melania lirata* Benson, 1836; *Melania semigranosa* von dem Busch in Philippi, 1842; *Melania batana* Gould, 1843; *Melania coffea* Philippi, 1843; *Melania flavida* Dunker, 1844; *Melania verrucosa* Hinds, 1844; *Melania crenifera* Lea, 1850; *Melania lateritia* Lea, 1850; *Melania microstoma* Lea, 1850; *Melania rudis* Lea, 1850; *Melania granospira* Mousson, 1857; *Melania broti* Reeve, 1859; *Melania lyrata* Reeve, 1859; *Melania chokolatum* Brot, 1860; *Melania granospiralis* Zollinger, 1860; *Melania asperula* Brot, 1868; *Melania obliquigranosa* Smith, 1878; *Melania junghuhni* Martin, 1879; *Melania tjariangensis* Martin, 1905; *Melania kritjianensis* Martin, 1905; *Melania tjibodasensis* Leschke, 1914; *Melania margaritana* Leschke, 1914; *Melania martini* Oostingh, 1935.

Material examined. BOR/MOL546, BOR/MOL3109, BOR/MOL3382, BOR/MOL6721, BOR/MOL8683, BOR/MOL8684, BOR/MOL8685, BOR/MOL8686, BOR/MOL8687, BOR/MOL8688, BOR/MOL8689, BOR/MOL8691.

Distribution and habitat. Widely-distributed throughout the state, found from Nabawan, Keningau, Sepitang, Tuaran, Kota Belud, Pitas, Kota Marudu, Tawau. Most were collected from rivers.

Remarks. This species is widespread in most water bodies from India to Australasia (van Benthem Jutting 1956).

Acknowledgements

We would like to thank Siong Kiat Tan for help in identifying some of the species and for providing useful references and comments. In addition, we thank many of our colleagues and students who collected the specimens and deposited at *BORNEENSIS*, Universiti Malaysia Sabah. The sampling on the islands of the west coast of Sabah by TSL and JD was supported by Research Acculturation Grant Scheme (RAGS), Ministry of Higher Education Malaysia (RAG0063-STWN-2015), and AZ's fieldwork in Sabah was supported by the Mohamed bin Zayed Species Conservation Fund (Project 152510591). We appreciate valuable comments from Frank Köhler, Thomas von Rintelen, and an anonymous reviewer which improved this manuscript.

References

- Adams A (1885) Descriptions of two new genera and several new species of Mollusca, from the collection of Hugh Cuming, esq. Proceedings of the Zoological Society of London 23: 119–123.
- Adams H (1874) Descriptions of some new species of shells from various localities, also of a new genus of bivalves from Mauritius. Proceedings of the Zoological Society of London 1874: 584–586. <https://doi.org/10.1111/j.1096-3642.1874.tb02514.x>
- Ali JH (1993) The distribution of *Physa acuta* Draparnaud (Gastropoda: Physidae) in Malaysia and its suitability as test material for insecticide toxicity studies. Journal of Medical and Applied Malacology 5: 129–134
- Aldrich TH (1889) Notes upon a collection of shells from Borneo with descriptions of new species. The Journal of the Cincinnati Society of Natural History 12: 23–26.
- Bock C (1881) List of land and freshwater shells collected in Sumatra and Borneo, with descriptions of new species. Proceedings of the Zoological Society of London 49: 628–635. <https://doi.org/10.1111/j.1096-3642.1881.tb01317.x>
- Bouchet P (1997) Inventoring the molluscan diversity of the world: what is our rate of progress? Veliger 40(1): 1–11.
- Brandt RA (1974) The non-marine aquatic Mollusca of Thailand. Archiv für Molluskenkunde 105: 1–423.

- Chiew EW, Lim LHS, Ambu S (2009) Cercarial dermatitis In Kelantan, Malaysia an occupation related health problem. *International e-Journal of Science, Medicine, Education* 1: 69–73.
- Cianfanelli S, Talenti E, Bodon M (2016) *Mieniplotia scabra* (Müller, 1774), another gastropod invasive species in Europe and the status of freshwater allochthonous molluscs in Greece and Europe. *Mediterranean Marine Science* 17: 253–263. <https://doi.org/10.12681/mms.1331>
- Clements R, Koh LP, Lee TM, Meier R, Li D (2006) Importance of reservoirs for the conservation of freshwater molluscs in a tropical urban landscape. *Biological Conservation* 128(1): 136–146. <https://doi.org/10.1016/j.biocon.2005.09.023>
- Cowie RH (2015) The recent apple snails of Africa and Asia (Mollusca: Gastropoda: Ampullariidae: *Afropomus*, *Forbesopomus*, *Lanistes*, *Pila*, *Saulea*): a nomenclatural and type catalogue. The apple snails of the Americas: addenda and corrigenda. *Zootaxa* 3940: 1–92. <https://doi.org/10.11646/zootaxa.3940.1.1>
- Cuttelod A, Seddon M, Neubert E (2011) European Red List of Non-marine Molluscs. Publications Office of the European Union, Luxembourg, 98 pp.
- Eichhorst TE (2016) Neritidae of the World. Volume 2. Conchbooks, Harxheim, 672 pp.
- Glaubrecht M, Brinkmann N, Pöppe J (2009) Diversity and disparity ‘down under’: Systematics, biogeography and reproductive modes of the ‘marsupial’ freshwater Thiaridae (Caenogastropoda, Cerithioidea) in Australia. *Zoosystematics and Evolution* 85: 199–275. <https://doi.org/10.1002/zoos.200900004>
- Hayes KA, Joshi RC, Thiengo SC, Cowie RH (2008) Out of South America: multiple origins of non-native apple snails in Asia. *Diversity and Distribution* 14: 701–712. <https://doi.org/10.1111/j.1472-4642.2008.00483.x>
- Hayes KA, Cowie RH, Thiengo SC, Strong EE (2012) Comparing apples with apples: clarifying the identities of two highly invasive Neotropical Ampullariidae (Caenogastropoda). *Zoological Journal of the Linnean Society* 166: 723–753. <https://doi.org/10.1111/j.1096-3642.2012.00867.x>
- Hill DS, Shabdin ML, Pilcher N (1997) Provisional checklist of the Mollusca of Sarawak and Sabah. Faculty of Resource Science & Technology and Institute of Biodiversity and Environmental Conservation, University of Malaysia, Sarawak, Malaysia, 19 pp.
- Issel A (1874) *Molluschi Borneensi. Illustrazione Delle Specie Terrestri E D’Acqua Dolce Raccolte Nell Isola Di Borneo Dai Signori G. Doria E O. Beccari.* Tipografia del R. Istituto Sordo-Muti, Genova, 486 pp. <https://doi.org/10.5962/bhl.title.10704>
- Johnson PD, Bogan AE, Brown KM, Burkhead NM, Cordeiro JR, Garner JT, Hartfield PD, Lepitzki DA, Mackie GL, Pip E, Tarpley TA, Tiemann JS, Whelan NV, Strong EE (2013) Conservation status of freshwater gastropods of Canada and the United States. *Fisheries* 38(6): 247–282. <https://doi.org/10.1080/03632415.2013.785396>
- Joshi RC, Sebastian LS (Eds) (2006) *Global Advances in Ecology and Management of Golden Apple Snails.* Philippine Rice Research Institute, Neuva Ecija, 588 pp.
- Köhler F, Glaubrecht M (2001) Toward a systematic revision of the Southeast Asian freshwater gastropod *Brotia* H. Adams, 1866 (Cerithioidea: Pachychilidae): an account of species from around the South China Sea. *Journal Molluscan Studies* 67: 281–318. <https://doi.org/10.1093/mollus/67.3.281>

- Köhler F, Glaubrecht M (2002) Annotated catalogue of the nominal taxa of Southeast Asian freshwater gastropods, family Pachychilidae Troschel, 1857 (Mollusca, Caenogastropoda, Cerithioidea), with an evaluation of the types. *Zoosystematics and Evolution* 78: 121–156. <https://doi.org/10.1002/mmnz.20020780107>
- Köhler F, Dames C (2009) Phylogeny and systematics of the Pachychilidae of mainland South-East Asia - novel insights from morphology and mitochondrial DNA (Mollusca, Caenogastropoda, Cerithioidea). *Zoological Journal Linnean Society* 157: 679–699. <https://doi.org/10.1111/j.1096-3642.2009.00541.x>
- Köhler F, Seddon M, Bogan AE, Tu VT, Sri-aroon P, Allen DJ (2012) The status and distribution of freshwater molluscs of the Indo-Burma region. In: Allen DJ, Smith KG, Darwall WRT (Eds), *The Status and Distribution of Freshwater Biodiversity in Indo-Burma*. IUCN, Cambridge, UK and Gland, Switzerland. pp 66–89.
- Lim BL, Lim TW, Cheah W, Fong YL (1976) *Angiostrongylus malaysiensis* from Tuaran, Sabah, with reference to the distribution of the parasite in Malaysia. *The Southeast Asian Journal Of Tropical Medicine And Public Health* 7(3): 384–389.
- Liu L, Mondal MM, Idris MA, et al (2010) The phylogeography of *Indoplanorbis exustus* (Gastropoda: Planorbidae) in Asia. *Parasites & Vectors* 3: 57. <https://doi.org/10.1186/1756-3305-3-57>
- Lydeard C, Cowie RH, Ponder WF, Bogan AE, Bouchet P, Clark SA, Cummings KS, Frest TJ, Gargominy O, Herbert DG, Hershler R, Perez KE, Roth B, Seddon M, Strong EE, Thompson FG (2004) The global decline of nonmarine mollusks. *BioScience* 54(4): 321–330. [https://doi.org/10.1641/0006-3568\(2004\)054\[0321:TGDONM\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2004)054[0321:TGDONM]2.0.CO;2)
- Marwoto RM, Isnaningsih NR, Mujiono N, Heryanto, Alfiah, Riena (2011) *Keong Air Tawar Pulau Jawa* (Moluska, Gastropoda). Pusat Penelitian Biologi (LIPI), Bogor, Indonesia, 16 pp.
- Matsukura K, Okuda M, Cazzaniga NJ, Wada T (2013) Genetic exchange between two freshwater apple snails, *Pomacea canaliculata* and *Pomacea maculata* invading East and Southeast Asia. *Biological Invasions* 15(9): 2039–2048. <https://doi.org/10.1007/s10530-013-0431-1>
- Meier R, Dikow T (2004) Significance of specimen databases from taxonomic revisions for estimating and mapping the global species diversity of invertebrates and repatriating reliable specimen data. *Conservation Biology* 18(2): 478–488. <https://doi.org/10.1111/j.1523-1739.2004.00233.x>
- Miller J, Agosti D, Penev L, Sautter G, Georgiev T, Catapano T, Patterson D, King D, Pereira S, Vos R, Sierra S (2015) Integrating and visualizing primary data from prospective and legacy taxonomic literature. *Biodiversity Data Journal* 3: e5063. <https://doi.org/10.3897/bdj.3.e5063>
- Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. <https://doi.org/10.1038/35002501>
- Ng TH, Kahar RS, Marshall DJ (2015a) Preliminary checklist of the freshwater Gastropoda of Brunei. *Occasional Molluscan Papers* 4: 1–5.
- Ng TH, Tan SK, Low MEY (2014) Singapore Mollusca: 7. The family Ampullariidae (Gastropoda: Caenogastropoda: Ampullarioidea). *Nature in Singapore* 7: 31–47. <https://doi.org/10.3391/bir.2015.4.3.06>

- Ng TH, Tan SK, Yeo DCJ (2015b) Clarifying the identity of the long-established, globally-invasive *Physa acuta* Draparnaud, 1805 (Gastropoda: Physidae) in Singapore. *BioInvasions Records* 4: 189–194.
- Ng TH, Tan SK, Foon JK, Chan MKK, Yeo DCJ (2016a) First non-native establishment of the carnivorous assassin snail, *Anentome helena* (von dem Busch in Philippi, 1847). *BioInvasions Records* 5(3): 143–148. <https://doi.org/10.3391/bir.2016.5.3.04>
- Ng TH, Liew JH, Song JZE, Yeo DCJ (2016b) First record of the cryptic invader *Pyrgophorus platyrachis* Thompson, 1968 (Gastropoda: Truncatelloidea: Cochliopidae) outside the Americas. *BioInvasions Records* 5: 75–80. <https://doi.org/10.3391/bir.2016.5.2.03>
- Ng TH, Tan SK, Wong WH, Meier R, Chan SY, Tan HH, Yeo DCJ (2016c) Molluscs for sale: assessment of freshwater gastropods and bivalves in the ornamental pet trade. *PloS One* 11(8): e0161130. <https://doi.org/10.1371/journal.pone.0161130>
- Page RD (2016) DNA barcoding and taxonomy: dark taxa and dark texts. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371(1702): 20150334. <https://doi.org/10.1098/rstb.2015.0334>
- Pointier JP (1999) Invading freshwater gastropods: some conflicting aspects for public health. *Malacologia* 41: 403–411.
- Régnier C, Fontaine B, Bouchet P (2009) Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conservation Biology* 23(5): 1214–1221. <https://doi.org/10.1111/j.1523-1739.2009.01245.x>
- Shabdin ML (2010) Macrofauna of Rajang River, Sarawak, Malaysian Borneo. *Journal Of Tropical Biology And Conservation* 7: 11–30.
- Smith EA (1894) Notes on the species of *Paludomus* inhabiting Borneo. *The Journal of Malacology* 3: 49–51.
- Smith EA (1895) Observations on the genus *Clea*, with the description of a new species. *Proceedings of the Malacological Society of London* 1: 251–253.
- Solem A (1964) A collection of non-marine mollusks from Sabah. *Sabah Society Journal* 11: 1–40.
- Strong EE, Gargominy O, Ponder WF, Bouchet P (2008) Global diversity of gastropods (Gastropoda, Mollusca) in freshwater. *Hydrobiologia* 595(1): 149–166. <https://doi.org/10.1007/s10750-007-9012-6>
- Supian Z, Ikhwanuddin AM (2002) Population dynamics of freshwater molluscs (Gastropod: *Melanoides tuberculata*) in Crocker Range Park, Sabah. *ASEAN Review of Biodiversity and Environmental Conservation* July-September 2002: 1–9.
- Tan SK, Chan SY, Clements GR (2012) *A Guide to Snails and Other Non-marine Molluscs of Singapore*. Science Centre Singapore, Singapore, 176 pp.
- Teo SS (2001) Evaluation of different duck varieties for the control of the golden apple snail (*Pomacea canaliculata*) in transplanted and direct seeded rice. *Crop Protection* 20(7): 599–604. [https://doi.org/10.1016/S0261-2194\(01\)00029-1](https://doi.org/10.1016/S0261-2194(01)00029-1)
- Teo SS (2003) Damage potential of the golden apple snail *Pomacea canaliculata* (Lamarck) in irrigated rice and its control by cultural approaches. *International Journal of Pest Management* 49(1): 49–55. <https://doi.org/10.1080/713867835>

- Teo SS (2004) Biology of the golden apple snail, *Pomacea canaliculata* (Lamarck, 1822), with emphasis on responses to certain environmental conditions in Sabah, Malaysia. *Molluscan Research* 24(3): 139–148. <https://doi.org/10.1071/MR04009>
- TROPMED Medical Group (1986) Snails of medical importance in Southeast Asia. *The Southeast Asian Journal of Tropical Medicine and Public Health* 17: 282–322.
- Yahaya H, Nordin M, Hisham MNM, Sivapragasam A (2006) Golden Apple Snails in Malaysia. In: Joshi RC, Sebastian LS (eds) *Global Advances in Ecology and Management of Golden Apple Snails*. Philippine Rice Research Institute, Nueva Ecija, 215–230.
- van Benthem Jutting WSS (1956) Systematic studies on the non-marine Mollusca of the Indo-Australian archipelago: V. Critical revision of the Javanese freshwater gastropods. *Treubia* 23: 259–477.
- van Benthem Jutting WSS (1959) Catalogue of the non-marine Mollusca of Sumatra and of its satellite islands. *Beaufortia* 7: 41–191.
- von Martens E, Thiele J (1908) Beschreibung einiger im östlichen Borneo von Martin Schmidt gesammelten Land und Süßwasser-Conchylien. *Mitteilungen aus dem Zoologischen Museum in Berlin* 4: 251–294.

Supplementary material I

Collection data, image links and distribution data for freshwater snails of Sabah deposited in the BORNEENSIS collection, Universiti Malaysia Sabah

Authors: Ting Hui Ng, Jasrul Dulipat, Junn Kitt Foon, Manuel Lopes-Lima, Alexandra Zieritz, Thor-Seng Liew

Data type: KMZ file

Explanation note: A KMZ file consisting of collection data, image links and distribution data. <https://figshare.com/s/1d2e39c49f1e5eaa0840>, <https://doi.org/10.6084/m9.figshare.4725562.v1>

Copyright notice: This dataset is made available under the Open Database License (<http://opendatacommons.org/licenses/odbl/1.0/>). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Supplementary material 2

A spreadsheet of collection and distribution data for freshwater snails of Sabah deposited in the BORNEENSIS collection, Universiti Malaysia Sabah

Authors: Ting Hui Ng, Jasrul Dulipat, Junn Kitt Foon, Manuel Lopes-Lima, Alexandra Zieritz, Thor-Seng Liew

Data type: Microsoft Excel spreadsheet

Explanation note: A Microsoft Excel spreadsheet file consists of detailed collection and distribution data. <https://figshare.com/s/1d2e39c49f1e5eaa0840>, <https://doi.org/10.6084/m9.figshare.4725562.v1>

Copyright notice: This dataset is made available under the Open Database License (<http://opendatacommons.org/licenses/odbl/1.0/>). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.